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HOW DID LIFE BEGIN AND CHANGE?

In this video, David Christian describes the Goldilocks Conditions on Earth that made it possible for life to form and prosper. He considers how life may have emerged near hydrothermal vents deep in the ocean and explains how some of the simplest organic molecules may have combined to form the first DNA. After reading the text below and watching the video, you should be able to explain why Earth is particularly suited for complex life and outline the story of how life changed in the past 3.8 billion years.

Key questions

1 What Goldilocks Conditions on Earth support the development of life?

2 How did Earth's composition and structure contribute to early life?

3 What don't we know about the origins of life?

Transcript: How did life begin and change?

0:12-0:59

5–30 MILLION SPECIES ON EARTH TODAY

How many different species of living organisms do you think exist on our tiny planet? The truth is we don't really know. Estimates range from perhaps 5 million to perhaps as many as 30 million, and it could be a lot more than that. That's staggering variety, and that's only a tiny fraction of all the species that have existed in the history of life which extends over almost 4 billion years.

Yeah, life really is mysterious, but there is actually quite a lot we know about it. We've seen that. We know some of the main characteristics of life, and we also have a pretty good idea of how and why life changes over time. What we're going to do in this unit is we're going to survey the history of life over almost 4 billion years.

1:00-1:50

THRESHOLD 5: LIFE

We'll begin with the origins of life. That, remember, is our fifth major threshold in this course. And then what we're going to do is we're going to look at a series of smaller turning points. We call them mini-thresholds. These are times when something new appears that seems to be slightly more complex than the things that existed before. And all of this, of course, is pointing to the creation of our own species, *homo sapiens*.

We begin with the origins of life. Now remember, this is the fifth major threshold of increasing complexity in our course, and let me remind you what we mean by thresholds of increasing complexity. At each of these thresholds, something new seems to appear in the Universe, something with entirely new qualities. Now, each time we've crossed these thresholds we've asked similar questions.

1:50-3:04

EARTH PROVIDED THE GOLDILOCKS CONDITIONS FOR LIFE

So when we talked about the first threshold — the creation of the Universe — or the creation of the stars or the creation of new chemical elements, or the creation of planets, we asked, what were the Goldilocks Conditions that made it possible to cross that threshold? So let's ask the same question about life.

Now, with life there is a problem because biologists suspect that there's life all through the Universe, but the truth is we don't know. The only place in which we're sure life appeared is on our planet. So that's the only place we can really study it. So let's rephrase the question. What were the Goldilocks Conditions for the origins of life on Earth?

Now, we can start with the fact that living organisms consist of very, very complex chemicals. They're not just large; they're also organized in very precise structures, whereas non-living things consist of very simple molecules. So to get life, you need environments in which you can do really exotic, really interesting, really elaborate chemistry. So where do you find conditions such that atoms can combine in all sorts of exotic forms?

3:04-3:42

THREE GOLDILOCKS CONDITIONS

ROCKY PLANETS ARE RICH WITH DIFFERENT ELEMENTS

Let's recall that in space — you can do simple chemistry — atoms can combine to form molecules with perhaps 10, 20, 30, never more than 100 atoms. But rocky planets like our Earth, it turns out, are wonderful environments for good chemistry. There are three reasons for this. The first is that they contain a great diversity of different elements, and above all they contain those elements that you need for organic life. The crucial ones are carbon, there's lots of hydrogen of course, there's also oxygen, nitrogen. These are all elements that were formed in dying stars, and also a bit of phosphorous and sulfur.

3:42-4:47

THE RIGHT LEVEL OF ENERGY

The second Goldilocks Condition is energy. This is subtle. You mustn't have too much. If there's too much you blast complex molecules apart, but you mustn't have too little. If there is too little there is not the energy for atoms to combine. The Earth was perfect. It was near a star so it had energy, but not too much. It also had energy coming up from its hot, molten core.

WATER PROVIDES A GOOD ENVIRONMENT FOR ATOMS TO LINK UP

Now, the third Goldilocks Condition is slightly subtler. It's the presence of liquids and above all, of water. Why? Well, think about it. In gases, atoms are moving around incredibly fast and it's very hard for them to link up, but in solids, atoms are stuck. They are stuck in a grid, like bad traffic, like a traffic jam. But in liquids, they can cruise past each other so it's much easier for them to hitch up in all sorts of complex forms. So here are three Goldilocks Conditions. The early Earth was almost perfect for elaborate chemistry.

4:47-5:41

DEEP SEA VENTS ARE A RICH CHEMICAL ENVIRONMENT FOR MOLECULAR DEVELOPMENT

We've seen that all these Goldilocks Conditions existed on the early Earth. Probably the ideal place for elaborate chemistry was deep beneath the oceans at cracks in the Earth's crust — mid-oceanic vents. These were ideal because you've got lots of chemicals seeping up from the mantle and you've also got lots of energy.

We know now that under these conditions it's fairly simple to create the simplest organic molecules that appear in all living organisms. I'm talking about molecules with just 10, 20, 30 atoms in them such as amino acids, which are the basis of all proteins, or nucleotides, which are the basis of DNA. We also know that it's not too hard under these conditions to string those simple molecules together in huge chains to form proteins and nucleotide molecules.

5:41-6:11

RESEARCHERS CONTINUE TO EXPLORE EARLY LIFE DEVELOPMENT

What gets tricky is the next stage. How, with lots of these large molecules to bring them together to form cells with membranes — they're like skins — and also with DNA at their center. But most biologists are pretty confident that though there is still some mystery here, they'll work it out in the next 20…10, 20 years.